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Editorial Comment

Another Measurement of Cardiac Output: Is It Truly Needed?*

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Measurement of cardiac output is a time-honored technique for evaluating cardiovascular function and has been of great interest to physiologists and clinicians since the beginning of the century (1). Cardiac output is currently clinically utilized in assessing systolic function of the heart and in calculating vessel resistance, stenotic valve area and intracardiac shunts.

Previous methods of cardiac output measurement. A wide variety of methods to measure cardiac output have been developed. Of the techniques currently employed, the Fick oxygen method and the indicator-dilution method, each have theoretical and practical limitations and require invasive instrumentation. Difficulty in precise measurement of oxygen consumption, a procedure that is time consuming, tedious and prone to error, is the major limitation of the Fick method (2). The indicator-dilution test, currently done with a bolus injection of indocyanine green dye, assumes adequate mixing of the dye and utilizes an extrapolation to establish the linearity of the downslope of a curve before recirculation supervenes (1,3). Overall, there is about a 15% difference in values obtained by the Fick and the indicator-dilution method (4). Because of the equipment required and the need for arterial and venous cannulation, both techniques are still limited to the cardiac catheterization laboratory.

The thermodilution technique allows a rapid and reproducible measurement of cardiac output and requires only right heart catheterization (5). Because it is also an indicator-dilution method, it is prone to the same errors as the indocyanine green dye method. Comparison of cardiac output by green dye versus thermodilution techniques has shown differences ranging from +16% to −17% (6) with a wider scatter of differences when the technique is compared with the Fick method (7,8). Minimal changes in injection technique may produce larger errors (9).

Doppler echocardiography is another method by which cardiac output can be determined through measurement of the velocity of blood across a valve orifice or within a great vessel (10–15). Its major clinical advantages are that it is noninvasive and allows beat to beat measurement of stroke volume. There are, however, assumptions made in using the Doppler principle to determine cardiac output. These include 1) assumption of a fixed circular orifice; 2) assumption of a flat velocity profile; and 3) knowledge of the angle of incidence between the Doppler beam and blood flow. Despite these assumptions, multiple studies have demonstrated a correlation of cardiac output with other standard techniques that is within the error of these methods.

The Doppler pulmonary artery catheter. In the current issue of the Journal, Segal et al. (16) present their initial experience with a newly developed catheter that incorporates the Doppler method for measuring cardiac output. By utilizing sophisticated methodology, a catheter placed in the pulmonary artery can record the instantaneous velocity profile over space as well as the instantaneous diameter of the vessel. This ability should theoretically overcome the limitations imposed on previous Doppler methods, albeit at the expense of requiring invasive instrumentation. Continuous sampling allows determination of rapid changes in stroke volume. This technique requires assumption of a symmetric flow profile and circular vessel area, a stable catheter position and an accurate knowledge of the angle of the Doppler beam in all dimensions. If the possible limitations of this catheter can be overcome, as the authors suggest, it has the potential to provide the most accurate method of measuring cardiac output clinically available.

The question that arises is whether this degree of accuracy in measuring cardiac output is needed in clinical practice. In the first half of the century, great emphasis was placed on developing methods to measure cardiac output, as there was no other way to determine cardiac function (1). With the advent of noninvasive imaging modalities, such as two-dimensional echocardiography, radionuclide angiography and cine-computed tomography, myocardial function can be directly assessed, lessening the need for accurate cardiac output measurements in the management of the patient with hemodynamic stability. Cardiac output measurement by thermodilution is still utilized for short-term management of the patient in unstable condition in the critical care setting (17). However, it is doubtful that the "significant" but small difference between cardiac output obtained by the Doppler catheter versus the thermodilution method would change the clinical management of such a patient. The clinical utility of monitoring immediate changes in cardiac output in the critically ill patient needs to be further assessed. The introduction of a pulmonary artery

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catheter that continuously monitors mixed venous oxygen saturation (18), indirectly assessing instantaneous changes in cardiopulmonary function, has not had a major impact on critical care medicine. The need for precise cardiac output measurement in the derivation of "valve areas" has been largely supplanted by noninvasive Doppler determination of aortic valve area (by the continuity equation) (19) and mitral valve area (by determination of pressure half-time) (20).

Thus, for current applications, a more accurate measurement of cardiac output may not be clinically valuable. However, there are potential unique future applications for this catheter. In the era of heart and heart-lung transplantation, more information is needed about the right side of the heart and pulmonary circulation. Current measurements of systolic function of the heart are highly dependent on the loading conditions of the ventricle. Investigations (21) into the concept of time-varying elastance of the left ventricle have provided greater insight into the intrinsic contractility of the ventricle. With the ability to measure beat by beat stroke volume during varying loading conditions, the Doppler catheter may provide this information about the right ventricle. Other flow velocity measurements, such as rate of velocity acceleration and deceleration, may provide additional information about intrinsic myocardial function. The concept of vascular impedance may overcome the limitations of vascular "resistance" because it describes the relation between pulsatile blood flow and pressure and thus is the function of the physical characteristics of the vessel (22–24). To characterize impedance, it is necessary to have accurate instantaneous measurements of both flow and pressure, which may be possible with the Doppler catheter.

Conclusions. The pulmonary artery Doppler catheter described by Segal et al. (16) has the theoretic potential of providing one of the most accurate methods of measuring cardiac output, but a more accurate invasive method may not be necessary for clinical use. In addition, as technology becomes more sophisticated, the cost of the instrumentation increases as does the risk of potential breakdown. However, as with any new technique or instrument, the potential applications are yet to be fully realized and, in the future, this catheter may provide unique information about the heart and circulation.

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